

September 10, 2004

DECLARATION

The undersigned, Jan McLin Clayberg, having an office at 5316 Little Falls Road, Arlington, VA 22207-1522, hereby states that she is well acquainted with both the English and German languages and that the attached is a true translation to the best of her knowledge and ability of international patent application PCT/DE 03/03324 of Stroebel, W., et al., entitled "WINDING MACHINE AND METHOD FOR PRODUCING A WINDING".

The undersigned further declares that the above statement is true; and further, that this statement was made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or document or any patent resulting therefrom.

  
Jan McLin Clayberg

~~6 P6D~~WINDING MACHINE AND METHOD FOR PRODUCING A WINDING

## Prior Art

5

The invention relates to a winding machine and to a method for producing a winding, in accordance with the characteristics of the independent claims.

In known winding machines, a wire is wound in more or less many loops around a winding carrier or a coil. After the predetermined number of windings, the winding wire is capped; the single coil is removed and typically mounted on a stator tooth intended for it. Once this has been done for a multi-pole stator, for instance, such as one with 36 single coils, a total of 72 wire ends of the individual coils have to be interconnected in the desired manner. Thus not only is the effort for producing the single coils great, but the effort for producing the desired interconnection of the stator winding is disproportionately great.

## Advantages of the Invention

With the characteristics of the first independent claim, according to which a winding machine with a carrier device for winding a winding for an electrical machine is provided, and this winding machine has at least one group comprising a winding template and an adjacent deflection element, and the winding template and the adjacent deflection element are displaceable relative to one another, have the advantage that as a result, each individual winding template is freely accessible for being wound, making industrially suitable production of an integrally embodied winding with a plurality of loops possible. With the provisions recited in the dependent claims, advantageous refinements of the winding machine of the first independent claim are possible.

30

If a row of groups is followed by a final winding template, a coil or winding becomes possible which has both a first and a last coil or winding on its respective ends. Since typically a partial voltage of the same magnitude is generated in each coil, the beginning and the end of the wire for one entire phase winding are

therefore both located on the same side. The effort and expense for wiring the individual phases, for instance in a delta circuit or Y circuit, even with a rectifier, is only slight.

5        In a further embodiment, it is provided that the carrier device is rotatable about a pivot axis. This rotatability makes an especially effective winding of one complete phase possible, since the energy input is less, compared with an alternative arrangement. An alternative arrangement would comprise the rotatability of the wire store and wire delivery. However, the latter would have to  
10      rotate about a markedly longer radius, so that the load on these components would be markedly greater. The energy input would furthermore be increased as a result.

15      If the pivot axis of the winding machine is displaceable relative to the carrier device, then the winding template can adjust in such a way that the pivot axis is located inside the winding template around which the winding is to be done. This makes economical winding of the individual windings or coils about the respective winding template possible with a virtually uniform wire delivery speed, both in the wire delivery or wire guidance, and at the winding cheek itself.

20      It is also provided that the winding template has an edge on one free end. If initially a relatively simple prismatic shape of winding template is assumed, this edge represents an excess length. Once this prismatic body of the winding template has been wound and such a winding template has been displaced in its axial position, then because of the relationships of the wire to other winding templates or deflection elements, the result could be that the wire slips downward from the winding template that is to be displaced. This must absolutely be avoided if a correct winding operation is to be achieved.

25      For producing an electrical machine, it is desirable for the stator and its winding, or the winding heads thereof, to have as uniform a construction as possible, to avoid asymmetries and hence to keep differences in cooling and flow as slight as possible. This also involves flow noises, which are equally unwanted. For this reason, it is provided that in the winding of the wire about a winding

template, a regularly ordered construction of a single coil is already attained early. For this purpose, at least one separator element is provided on the cheek sides of the winding template, so that when a multiple wire is wound, the at least two wires finally come to rest on one another. Other reasons for such separator elements

5 are for instance when rectangular wires are used, that is, wires whose cross section is approximately a rectangle and whose winding or bending around the cheek sides is done with the greatest possible bending resistance, in order absolutely to avoid unwanted shifting of the deflection sides of a wire segment. Such deflection or tipping over of such a deflection wire would cause the winding

10 heads to have an undesirably great radial structure relative to their position in an electrical machine.

In a further embodiment of the winding machine, it is provided that the winding machine has at least two stepped rests, each for at least one wire, for graduating the coil width within a coil. The coil width is considered here to be the length of a coil in the direction of the later axial direction of the electrical machine. As a result of the stepped rest, at least two wire segments are attained which because of their axial length are located in different positions and can be accommodated in a space-saving way in the winding head. This keeps a winding head small in its

15 radial length.

20

It should be possible for the finished wound winding to be removed from the winding templates as simply as possible, and thus without overly great mechanical resistance. To that end, it is provided that the at least one winding template

25 comprises at least two winding cheeks that are adjustable relative to one another. For instance, a free edge on the end of a winding template or separator elements are adjustable such that it presents no obstacle to the removal of the winding from the or the winding template.

30 Either both winding cheeks may be adjustable relative to one another, or only one may be adjustable. For the winding operation, it is desirable for the winding operation to proceed without vibration problems of varying nature, so that the at least one wire can be delivered via a wire guide which avoids such vibration problems.

To reinforce the winding operation and in particular the ordered arrangement of the individual loops on a winding cheek, it is provided that the wire guide is adjustable in accordance with a winding progress relative to a winding cheek. This  
5 adjustment includes both an adjustment of the wire guide relative to a nonadjustable carrier element and an adjustment of the carrier element relative to the nonadjustable wire guide.

In a coordinate claim, a method for producing a winding from at least one coil  
10 is provided, in which at least one wire can be wound about a winding template, resulting in at least one wire arrangement with at least one first coil side, at least one first deflection side, and at least one second coil side, and a winding template is displaced out of a plane for the winding process. By this method, on the one hand a single winding template becomes accessible all the way around, and on  
15 the other, a winding that has a plurality of coils can be produced by means of a tool.

By the provisions recited in the following dependent claims, advantageous refinements of the method for producing a winding in accordance with the  
20 coordinate claim are possible. For instance, after the coil has been wound, the winding template with the coil is pushed back into the plane, so that following winding templates can be freely wound. For integrally connecting the individual coils, it is provided that after the first coil is wound, at least one wire is wound about an adjacent deflection element in a second direction of rotation, to produce  
25 a coil connector.

#### Drawings

Fig. 3, a carrier device of the winding machine, in an initial position in a side  
30 view;

Figs. 4A, 4B and 4C, various exemplary embodiments of a winding template  
29;

Fig. 5, the carrier device in the first working position, in a side view;

Fig. 6, the carrier device in the first working position, in a plan view;

5 Fig. 7, the carrier device in the first deflected position, in a plan view;

Fig. 8, the carrier device after the winding of a first deflection element, in a side view, before a second coil is wound;

10 Fig. 9, the carrier device in a second working position, that is, in the position in which the second coil is wound;

Fig. 10, the carrier device in the second working position, in a plan view;

15 Fig. 11, the carrier device after one complete, single wave winding has been wound, in a plan view;

Figs. 12A and 12B, a coil on a winding template, in two side views;

20 Fig. 13, a single coil with an offset winding head; and

Fig. 14, a fragmentary view of a stator with a single coil, shown in section, with an offset winding head;

25 Fig. 15, a fragmentary view of a winding template with a double wire.

#### Description

In Fig. 1, a winding machine 20 with a carrier device 23 is shown, for winding a winding for an electrical machine. The carrier device 23 is displaceably secured in a holder 26. Both winding templates 29 and deflection elements 31 are secured to the carrier device 23. A first winding template 29.1 and a first adjacent deflection element 31.1 form a first group 34, which is the minimum necessary for the function of the machine. In principle, the number of groups 34 is unlimited. The

winding template 29.1 and the adjacent deflection element 31.1 are displaceable relative to one another, as will be explained in further detail for subsequent drawings. Each winding template 29 is displaceable relative to a deflection element 31. The carrier device 23 is rotatable about a pivot axis 36. To that end,  
5 the holder 26 is driven via a shaft 28 and thus carries the carrier device 23 along with it.

The pivot axis 36 is displaceable relative to the carrier device 23. In this concrete exemplary embodiment, this means that the carrier device 23 is  
10 displaceable in the holder 26, so that the intrinsically fixed pivot axis 36 is displaced relative to the carrier device. In the view shown, the pivot axis 36 is inside the first winding template 29.1.

In Fig. 2, the winding machine 20 described in conjunction with Fig. 1 is shown  
15 in an end-on view as in Fig. 1. Via a wire guide 40, at least one wire 41 can be delivered to the winding machine 20.

Fig. 3, in a schematic view, shows an arrangement of three groups 34, each having one winding template 29 and one deflection element 31. The groups, three  
20 of them in this example, form one row, which is followed by a final winding template 29.4. The winding template 29 and the deflection elements 31 are seated on the carrier device 23, which is shown in section here.

Before the function and mode of operation of the winding machine 20 is  
25 described further, the functions of the winding templates 29 will be explained in various exemplary embodiments.

In Fig. 4A, a first exemplary embodiment of a winding template 29 is shown. The winding template 29 comprises two winding cheeks 45, which are seated on a  
30 cheek holder 48 to which one wire end 42 (the beginning of the wire) is secured. This exemplary embodiment of the winding template 29, or in other words the winding cheeks 45 shown there, have an edge 54 on one free end 51. The function of this edge will be explained later. In addition, the winding cheeks 45 and thus the winding template 29, on their cheek sides 56, have at least one separator

element 58. The separator elements serve to enable winding the wire or wires 41 at defined positions, for instance in order to prevent twisting of rectangular wires around themselves or in the wire direction, or in the case of a double round wire, that is, when two round wires are wound simultaneously, to enable avoiding an offset relative to one another; see also Fig. 15. Once a wire 41 has been wound around a winding template 29 of this kind, the individual wire windings 62 are located in slots 60 disposed between the separator elements 58. In order finally to be able to remove the individual wire windings or completely wound coils from the individual winding templates 29, it is necessary that the winding cheeks 25 be moved relative to one another. In this case, this means that the winding cheeks 45 must be moved toward one another. The separator elements 58 are so short, or the slots 60 are so shallow, that by simply pushing the winding cheeks 45 toward one another - as indicated by the double arrow - the wire windings 62 emerge from the slots 60 and finally leave them. The wire windings 62 have such high intrinsic stability that they hardly change position at all, except for the known elastic component. Once the winding cheeks 45 have been pushed together and the wire end 42 has been released, a winding can be removed from its winding template 29.

In Fig. 4B, a further exemplary embodiment of a winding template 29 is shown, which takes the example shown in Fig. 4A as its point of departure. Once again, the winding cheeks 45 described above are present, which are seated on the cheek holder 48. There is one edge 54 on each of the free ends 51. On the cheek sides 56, the separator elements 58 and slots 60 described above are also present. In a distinction from the exemplary embodiment of Fig. 4A, however, the winding template 29 has at least two stepped rests, each for at least one wire 41, to enable stepping down a coil width within one coil. These at least two stepped rests are each formed by one slot base 65. If a wire 41 is wound around such a winding template 29, or such winding cheeks 45, then it can be seen that the coil width overall is variable. Specifically, there is a lower region with a relatively wide coil width, but above it, later, there is a winding portion or coil portion with a reduced coil width, which is due to the fact that the wire is wound over the different rests.

In Fig. 4C, a somewhat simpler exemplary embodiment of a winding template 29 is shown. Once again, this winding template comprises two winding cheeks 45, which each have one edge 54 on their free end 51. In this case, the wire is wound around the winding template 29 without separator elements 58 and slots 60. This  
5 can easily be done using simple round wire 41, without making further demands in terms of the design of the winding. However, since here as well a change in position of the winding template 29 relative to an adjacent deflection element 31 is intended, the edge 54 is required here as well, to prevent the winding from slipping unintentionally down from the winding template 29.

10

The method for producing a winding from at least one coil will now be described. In this connection, further details of the machine will be explained. After the fixation of a wire end 42 to the first winding template 29.1 using a fastening element 66 (see also Fig. 3), the winding template 29.1 is lifted or displaced out of  
15 a common plane shared with the further winding templates 29 and the deflection elements 31; see also Fig. 5. The first winding template 29.1 is then in the position of the pivot axis 36. The winding template 29.1 is displaced so far out of the plane that the lowermost slot 60 is above the remaining deflection elements 31 and winding templates 29.

20

After this displacement of the winding template 29.1, the entire carrier device 23, already described in conjunction with Fig. 1, is rotated with the holder 26, by means of the shaft 38, about the axis 36, but the wire guide 40 is at least not rotated. As a result of this rotation of the entire carrier device 23 and thus also of  
25 the first winding template 29.1, the wire is wound around the first winding template 29.1, resulting in at least one wire arrangement with at least one first coil side 68, at least one first deflection 69, and at least one second coil side 68; see also Fig. 6. The winding around the first winding template 29 or 29.1 is done in a first direction of rotation in order to produce a first coil. In a further step, a first coil  
30 connector 70 is wound around the deflection element 31.1. To that end, the second coil side 68, or an extension of it in the direction of the wire guide 40, is wound by opposite rotation in a second direction of rotation, opposite the first, around the deflection element 31.1; see also Fig. 7. To that end, the pivot axis 36 is adjusted to the deflection element 31.1, by displacement of the carrier device 23

in the holder 26. For winding the second coil around the second winding template 29.2, the first winding template 29.1 is pushed back into the plane again; see also Fig. 8.

5 In a further work step, the second winding template 29.2 - as has already been done for the first winding template 29.1 - is displaced out of the plane, so that the winding can also be done freely around this winding template 29; see also Fig. 9. A second coil is wound around the second winding template 29.2, so that once again a first coil side 68, a first deflection side 69, and at least one second coil side 68 are located around, or have been wound around, the winding template 29.2.  
10 This winding operation around the second winding template likewise takes place in a first direction of rotation, and once again the pivot axis 36 is adjusted to the second winding template 29.2; see also Fig. 10. Winding of the winding template 29 and deflection elements 31 is also done analogously until the final winding  
15 template 29.4; see also Fig. 11. If a single wave winding of this kind is wanted, for instance for a stator of an electrical machine, then the winding shown in Fig. 11 is complete upon the winding of the second coil side 68, and the wire 41 can now be capped. After that, the winding can be removed from the winding templates 29  
20 after the end of the winding operation. If the winding template 29 is equipped with an edge 54, as also shown in Figs. 5 through 11, then the winding can intrinsically not be pulled downward from the winding templates and deflection elements 31 unless further provisions are made. As already indicated in conjunction with Figs. 4A, 4B and 4C, because of the undercuts between the edges 54 and the wires 41, it is necessary for at least one second winding cheek 45 of a winding template 29  
25 to be adjusted so that the winding can be removed. As a result of the adjustment of the winding cheeks 41, the winding cheeks are located entirely within one winding, so that undercuts are eliminated and removal is simple.

30 If instead of a wave winding as in Fig. 11, a double wave winding is used, then after the second coil side 68 about the winding template 29.4, the wire should not be capped but should continue to be wound, so that a third coil side 68 around the winding template 29.4 is produced. Analogously to the steps involved in the winding operation from the winding templates 29.1 to the winding template 29.4, the wire 41 should however be wound backward along the respective other side of

the winding template 29 or deflection element 31.

To produce a single loop winding, the sequences described can easily be modified. The first step, as shown in Fig. 6, of winding the wire around the first 5 winding template 29.1 is the same, but after the second coil side 68 winding is not done in the same way around the deflection element 31 but instead, for instance with five windings, a single coil around the winding template 29.1 is produced; see also Figs. 12A and 12B. Only after that is a coil connector 70 produced by means of the deflection element 31.1, as already described in conjunction with Fig. 6. To 10 produce a complete, single coil winding, for this purpose windings are each wound in the desired number around a single winding template 29 until at the final winding template 29 or 29.4, a final second coil side 68 is wound, and then the wire is capped analogously to Fig. 11.

15 A single winding template 29 need not necessarily be pushed back into the plane in order to produce a coil connector 70. For instance if only a few windings are intended around one winding template 29, then the spacing from the top of a deflection element 31 is not excessive, and thus the wire between two coils does not become overly long, either. The larger or thicker a coil is around a winding 20 template 29, however, the more necessary it becomes, before winding around a deflection element 31 is done, first to push the winding template 29 with the coil back into the plane. Also for removing a single loop winding with a plurality of windings about a winding template 29, it is necessary, for removing the winding from the winding machine, to adjust the winding cheeks 45.

25 The winding template 29 shown in Fig. 4B, with the shoulders, leads to a coil with an offset winding head 74 each time; see also Fig. 13. This offset winding head has the advantage that the deflection sides 69 can assume various positions; see also Fig. 14. In Fig. 14, a stator 77 of an electrical machine is shown in 30 fragmentary form. Because of the axial offset of the deflection sides 69, it is possible to reduce the radial length of the winding head referred to the pivot axis of a rotor of the electrical machine and instead to increase its length in the axial direction. In Fig. 13, the radial direction is identified by an arrow and the letter r, while the axial direction is identified by an arrow and the letter a. To reduce the

radial length of the winding head, the axially outer deflection sides 69 are bent such that they are at least partly at the same radial height as the deflection sides 69 of the winding head that are located farther inward.

5 At the outset it was noted that the winding template 29 and the deflection elements 31 were adjacent. The word "adjacent" means here that each winding template 29 is followed by a deflection element 31, until the arrangement ends as needed with a final winding template 29. The deflection elements 31 and the winding templates 29 are arranged in a straight row, for reasons of practicability,  
10 although naturally other forms of rows, such as slightly curved ones, circular ones, or the like can be considered.

It is understood that the winding machine of the invention is suitable not only for processing profile wires 41, for instance of rectangular cross section, but also  
15 for winding conventional round wires 41; see also Fig. 4A. Moreover, because of winding cheeks 45 and separator elements 58, the winding machine is quite particularly suitable to be wound simultaneously with two round wires, or optionally even two rectangular wires. The separator elements 58 then bring about an unambiguous positional association of the individual wires and prevent them from  
20 slipping; see also Fig. 15.

It is also possible for each slot 60 to be wound multiple times with a simple wire.

25 When the individual winding template 29, lifted or displaced out of a plane, is being wound, the relative position between the wire guide 40 and the winding template 29 varies as a result of the winding. To avoid problems in wire delivery, for instance into the slots 60, it is provided that the wire guide 40 is adjustable in accordance with a winding progress relative to a winding cheek 45 or the winding template 29. As an alternative, it is possible to displace the entire carrier device 23  
30 with the holder 26 axially and thus once again to bring about a relative adjustment between the wire guide 45 and the winding template 29.

In the same way as the winding templates 29 are constructed of two winding

cheeks 45 that are displaceable relative to one another, the deflection elements 31 may also be constructed of two deflection cheeks displaceable relative to one another. This enables easy removal of the winding when wire of a particularly problematic shape is involved.